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Note: this is a condensed version of the paper which (will be) was given at the UCT NDT Workshop as a Power Point based presentation.

A STROLL THROUGH A MODERN RADIOSCOPIC INSPECTION SYSTEM

HISTORY

European Customs Fluoroscope Inspection (1897)

X-rays were discovered by Conrad Röntgen in the year 1895 and real-time Radiography – often called Radioscopy - was already known in 1897. It was initially applied to inspect baggage using a rudimentary fluorescent screen.

The underlying concept is an interpretation of the X-ray attenuation through the material to find internal defects by a 'shadow effect'.

It took a further 30 years for this discovery to become industrially viable and developments in this field have recently accelerated considerably to increase information content and resolution. They are driven by economic as well as information considerations and offer substantial savings in inspection time, in data storage, and in consumable materials that would be needed if film radiography were used.

Although limited to 26 mm steel equivalent penetration for real-time work, X-rays are preferred to other energy sources such as isotope and neutron radiation as they are easily and safely controlled in terms of intensity and direction. And they can be switched 'OFF'!

THE SYSTEM

A modern UT real-time RADIOSCOPIC INSPECTION SYSTEM requires at least the following components:

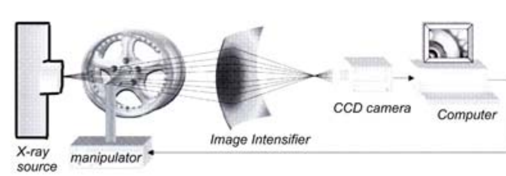


Diagram of a Radioscopic System

- An X-ray source comprising of: X-ray generator, X-ray Controller, X-ray tube HT cables and a cooling cicuit.
- A manipulator to move the test piece inside a radiation-proof safe containment within the X-ray beam.
- An X-ray image receiving device with intensification capabilities.
- A visual or camera interface.
- An image processing computer.

To further automate an inspection system the following components are frequently added:

- Image enhancing facilities
- An image evaluation computer.
- Image storage capability.

We will visit the main components in that order herunder.

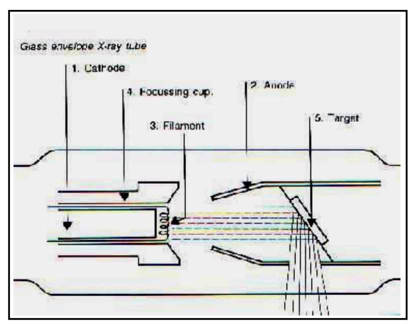
THE X-RAY SOURCE: X-RAY GENERATOR

The classic look X-ray generator is a transformer - based oil immersed, evacuated, 50 Hertz half - wave HT rectifier system. In this modern age we utilize low - Voltage, chopper - controlled converters to generate cathode heating and the high tension. Service ability as well as software control of the functions have become essential features in real-time Radiographic systems. High Voltage stability, which is critical for a fast inspection, has been improved to residual ripple < mV per kV.

THE X-RAY SOURCE: X-RAY CONTROLLER

Formerly the high-tension was controlled using a toroid low - Voltage transformer which was set manually to obtain the desired kV and mA, i.e. the desired energy quantum of X-rays, as an analog value.
Today, we utilize fully electronic digital control systems with additional facilities such as exposure programming, exposure logging and optimum power settings as well as automatic kV warm-up to protect the tube. The advantages of digital control are obvious where any a form of programming and program storage is used. All parameters are captured to ensure the reproducibility of each image.

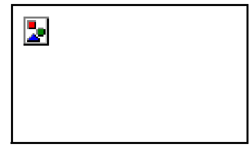
THE X-RAY SOURCE: X-RAY TUBE



X-ray tubes used to be made of fragile glass which permitted evacuation sufficient for insulation up to 420 kV. Today industrial X-ray tubes are manufactured of a metal - ceramic material, which can be used up to a maximum of 450 kV. In addition it is now possible to measure the focal spot accurately to permit an optimum X-ray exposure adjustment. It is not unusual for these modern tubes to have a life cycle expectancy of 80,000 hours when used in continuous, automatic inspection systems.

MANIPULATOR

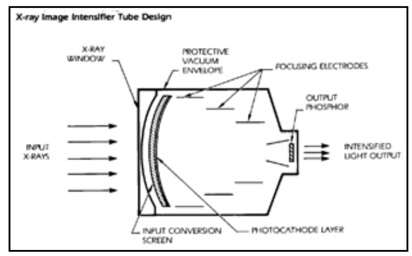
Whereas film Radiography requires a fixed position of the object between the X-ray beam up and the image recording film, the advantage of a real-time Radiographic system becomes apparent immediately because in it the testpiece can be moved in any direction during the exposure.



The test object position may be changed manually from outside the lead - lined safety Cabinet, (see pic) or by means of remote motor driven devices. The classic manipulator used analog motors whereas modern systems make use of digitally operated and controlled motion devices and feed-back encoders. These use freely - programmable PLC operated facilities which permit continuous parameter adjustment and accurate identification and logging the of the test object position in up to six axes. The X-ray Controller programs the PLC to synchronize the X-ray exposure parameters for a specific object position.

The future will show increased use of complicated multiple industrial robot- operated manipulation devices and especially faster, more accurate manipulators for tomographic inspections. Sel-teaching programs will become more sophisticated.

<u>IMAGE INTENSIFIER</u>

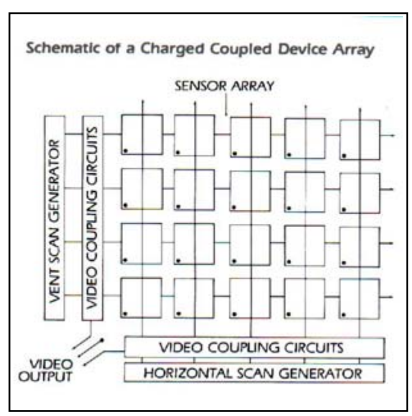


Perhaps the first ‘image intensifier’ was used in 1897 whereby a rudimentary fluorescent screen gave a vague visual image of the object. No further processing or image enhancement was possible.

Real progress in image intensifier design started in 1948 and became industrially viable in the 1960s when the introduction of modern television equipment caused a paradigm shift. The development of the Thomson Tube, which permits light amplification and the charge - coupled camera devices that digitize information on to a PC screen, are current state of the art.

The discovery of the flat panel detector (Focal Plane Array) and its sensitivity to X-rays offer a viable alternative, provided that the cost can be reduced to acceptable levels. It’s increased detection area with 16 bit/pixel grey value definition certainly offers the resolution which is desired to compete with the best of film Radiography. Light weight enhances the speed of typical C-frame manipulators. Currently, however, some difficulty with the equalization of pixel sensitivity remains.

<u>C C D CAMERA</u>



The development of the charge coupled device to a level where its resolution is equal to film with the information offered in digital format, has replaced the classic TV or visual inspection of the image. The CCD camera has become an integral part of the image intensifier system. Excellent geometric authenticity and HDTV resolution up to 2,2 million pixels coupled with high switching speeds offer untold advantages.

<u>IMAGE PROCESSING COMPUTER</u>

Prior to the advent of the computer it was not possible to either enhance the X-ray image or to record it. The optimum target has always been an excellent X-ray image for human interpretation. The processing computer is therefore it utilized a) to quickly optimize the X-ray exposure parameters to the current position of the specimen, and

b) to rapidly improve the image using electronic tricks such as image enhancement, integration, edge enhancement, and contrast improvement for a virtual live presentation of the image on the operator screen. The rapid development of higher processing speeds and the computer's creased resolution of images demands however, more and more storage capability where even the optical disc may not be adequate for industrial applications in mass production. On the positive side, this rapid development promises a future of real-time 3-D Tomography for the spatial positioning and sizing of the defect.

EVALUATION COMPUTER

The human 'computer' is unchallenged in the evaluation of real-time Radiographic images. Its downfall is the lack of objective reliability and continued, consistent concentration in an environment of fast and repetitive industrial inspections.

Where D I R (Direct Image Recognition) is desired, systems such as Seifert's SABA are commercially available. Such systems utilize algorithms to recognize, by logical assimilation of pixel information, variations in attenuation, type of defect such as inclusion, shrinkage, crack or density of porosity.

Add position information to the formula and it is possible to extract the severity of the defect within the test object and thus realistically accept/reject test pieces in accordance with a prescribed quality procedure.

THE FUTURE

In future increased processing capabilities will provide absolute measurement of a defect size and a link to correlate size and position to stress analysis considerations. This will finally determine whether a part is fit for it's design purpose.

Refinement of X-ray tubes may lead to new target materials that can take more heat and thus enable target area reduction to bring us closer to the ideal 'point source'. Increased efficiency from the current 99% heat and 1% X-rays is desirable.

The computer processing speeds only play a subjective role in terms of inspection time saving. It is predictable that future development will concentrate on improved manipulators and – with the FPA detectors – a reduction in the number of exposure positions without loss of safety-critical inspection data.

Today's real-time RADIOSCOPIC systems are so reliable, simple to operate, and flexible that they have become an indelible part of modern NDT. On the one hand they have offered cost-effective solutions in a mass production environment demanding 100 per cent inspection of all parts.

On the other hand, they have proved their value in one-off R&D where safety considerations, functional criticality or the value of the component demand intimate knowledge of internal structures.

BRo 20th February 2002